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CORPUSCULAR HYPOTHESIS FOR THE IONIZATION OF THE NIGHT IONOSPHERE

(Korpuskulyarnaya gipoteza ionizatsii nochnoy ionosfery)

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ABSTRACT

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On the basis of data on the distribution of electron concentration in the region of the F-layer of the night ionosphere at middle latitudes, and considering that it is basically conditioned by fluxes of soft electrons, the authors estimate the effective energy and the intensity of the electron flux, computing at the same time the electron energy spectrum.

The spectrum computed in the region with energies from 100 eV to $5 \cdot 10^4$ eV, may be approximated by the power function $E^{-\gamma}dE$ with $\gamma \sim 4$. The kind of the obtained spectrum agrees well with the energy spectra of electrons in the region of high energies, constructed according to currently well known experimental data.

Author

COVER-TO-COVER TRANSLATION

The investigation of the upper atmosphere with the help of rocket and satellite-born mass-spectrometers [1 – 4] has shown that the ionosphere contains a great quantity of N_2^+, O_2^+ and NO^+ ions even at very great altitudes of the $\sim$500 – 600 km range.

Oxygen is basically dissociated above 120 – 150 km [5], that is why the presence of O_2^+ ions above that level is unexpe

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But the great concentration of NO^+ ions is still more unexpected, for, according to the latest spectroscopic investigations [6], NO molecules are not present in the atmosphere in sufficient quantities. A. D. Danilov has shown in his works [7, 8, 9], that molecular ions are formed in the upper atmosphere as a result of photochemical reactions.

One of the important consequences of molecular ion concentration is the conclusion on the great intensity of recombination processes, and therefore of ionization in the ionosphere. It has been shown in [10] that these data on the rate of recombination and ionization processes in the daylight ionosphere are corroborated by new data on the intensity of Sun's short-wave ultraviolet and X- ray radiations.

Because of unusually high recombination rates, the ionosphere must be fully neutralized after sunset in a comparatively short time. According to the latest data on recombination coefficients [8, 9, 10], the electron concentration in the ionosphere F-layer maximum must drop ten times in 3 to 30 minutes and 100 times in 1 to 10 hours. At lower altitudes the neutralization process is still faster. In reality, although the electron concentration in the ionosphere diminishes after sunset, it still maintains a comparatively high level, being only 3 to 10 times lower than in daytime [11]. An analogus pattern is observed during solar eclipses. The ionosphere is also preserved during the periods of deep polar nights at high latitudes. Therefore the existence of a complementary source of ionization in the ionosphere is doubtless, though its nature still remains obscure.

Such peculiarities in the behavior of the night ionosphere and of the F-layer, as significant irregular oscillations in time of electron concentration, the dependence of layer's altitude ar of electron concentration on the geomagnetic latitude and the tence of local regions with increased ionization etc. compel assume that charged particles — corpuscules — are the so night ionization. This hypothesis is not only based upon data on the ionosphere, but also on various considerations of properties of the assumed corpuscular stream originating in the Sun [12].

The occurrence of the night sporadic E_s - layer and the other peculiarities of ionosphere behavior are correlated with the magnetic activity [13]. V. I. Krasovskiy [14], and later R. A. Zevakina [15], linked the origin of anomalous phenomena in the E and D-layers of the ionosphere during magnetic "bays" with the penetration of corpuscular streams into the lower part of the ionosphere. V. M. Driatskiy and A. S. Besprosvannaya [16] noted the presence of correlation between the night ionization of the F_2 - layer in the Arctica and the magnetic data (see also [17]), which, according to their opinion, indicates the corpuscular nature of the ionization. E. I. Mogilevskiy [18] attempted to make a quantitative estimate of the intensity ($\geqslant 10^2$ particle/cm^3) and the spectrum ($\gamma \simeq 0.6$) of the corpuscular stream according to ionospheric data. Ya. L. Al'pert, V. L. Ginzburg and E. L. Feynberg (see [19], p.638) introduced the corpuscular hypothesis as a possible explanation of the weel known effect of ionosphere's complementary ionization at the 20 to 30^o geomagnetic latitude. Besides the ionosphere, a series of other geophysical phenomena, such as aurorae and particularly the diffused aurorae [20], the night sky glow [21, 22], in which characteristic discrete glow regions are observed, the initial heating of the upper atmosphere [23, 24, 25] and others, correlate with the geomagnetic data, and they are ascribed to the action of cropuscular streams originating from the Sun [26, 27]. However, up until now, the nature of the mechanism of the deep penetration into the Earth's atmosphere, and through to ionosphere of a sufficientlt powerful solar corpuscular radiation has remained obscure [28]. That is why, all explanations of phenomena taking place in the upper atmosphere, linked with the corpuscular radiation hypothesis, were neither coherent nor conclusive.

Meanwhile, there are also direct indications to the effect that particle fluxes exist in the ionosphere and above it, of comparatively fast electrons. (As to the possible mechanisms of electron flux formation in the ionosphere, see below).

The idea of upper atmosphere ionization by corpuscules received a serious support after Van Allen and others [29, 30] detected with the aid of rockets rather intense electron fluxes even at comparatively low altitudes of $\sim$100 km [29]. The maximum of their intensity is observed in the aurora zone. However, these electron streams are very irregular and they apparently exist at all latitudes. In the experiments by the authors of references [31 and 32], a flux with an intensity of $\sim 10^{-2}$ erg/cm^2 at 80 to 100 km altitude was observed in the middle as well as in high latitudes.

Obayashi [33 - 36] communicated, that there appeared at the end of a magnetic storm a corpuscular stream having induced a sharp increase of electron density and a disturbance of the magnetic field. On the basis of the study of "whistler" propagation, Smith and others have established a columnar structure of the ionosphere above the F-layer maximum [37, 38]. Such columns may only form under the effect of local corpuscular streams.

An interesting result, obtained with the help of Explorer was communicated by O'Brien and al. [39]. A particularly powerful electron streams $\gg 10^4$ erg/cm^2 sec, was registered at 1600 km altitude precisely at the time the satellite was passing over an aurora arc (if one projects the satellite along the magnetic line of force), while only electrons with energies $E \gg 30$ keV were registered. An intense stream of corpuscular radiation was also observed at satellite's passing over a broadly stretched aurora arc, glowing in the 6300 Å line. The intensity of corpuscular radiation then diminished synchronically in time as the aurora glow was dying away.

The examples brought out thus demonstrate the existence of electron streams in the ionosphere at least at time of certain particular phenomena, such as aurorae, magnetic storms and others).

EFFECTIVE ENERGY OF ELECTRONS AND INTENSITY OF THE ELECTRON STREAM IN THE IONOSPHERE

It may be assumed on the basis of the aforesaid, that there is a large number of trapped electrons in all the regions of the Earth's magnetic field, and not only in radiation belts. [40]. Electrons spiral along the magnetic lines of force. It may be considered that a specific electron flux flows both ways along the tube of force. Wherever the magnetic tube of force, along which the electron stream flows, enters sufficiently dense atmosphere layers, frequent collisions of electrons with atoms and molecules of the atmosphere take place and the ionized layer – the ionosphere – thus appears.

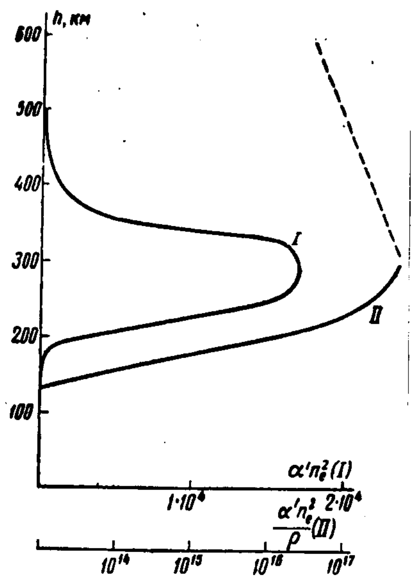

Fig. 1. Variation with altitude of the magnitudes $\alpha' n_e^2$ (I) and $\alpha' n_e^2$ (II) in the ionosphere.

The distribution of electron intensity along the tube of force will be determined on one part, by electron formation and by the distribution in the magnetic field of electron sources, and by electron vanishing from magnetic tubes on the other.

The source of fast electrons is unknown for the time being. Thus for the determination of the intensity and of the spectrum of the electron flux at various altitudes, we shall turn to ionospheric data. At the same time we shall assume that the basic cause of energy loss by the electrons resides in the non-elastic collisions with atmosphere particles, at which the main share of energy goes to the ionization. Let us roughly estimate the effective energy and the intensity of the electron stream, considering that the ionosphere ionization in nighttime conditions is only materialized by the stream of electrons.

Under equilibrium conditions the number **Q** of ions forming in 1 cm^3 in 1 second is equal to the number of recombinations $\alpha' n_e^2$, where n_e is the electron density at the given height <u>h</u>, α' being the effective recombination coefficient. If the intensity of electrons incident in 1 cm^2 per second from one steradian in a direction determined by the angles ϑ between the electron velocity vector and the vertical, and φ (azimuth), is $n(E, h, \vartheta, \varphi)$ cm^{-2} sec^{-1} $sterad^{-1}$, then

$$Q(h) = \int\limits_{E=0}^{\infty} \int\limits_{\vartheta=0}^{\pi/2} \int\limits_{\varphi=0}^{2\pi} n(E, h, \vartheta, \varphi) \rho f(E) \frac{1}{\cos\vartheta} \sin\vartheta \, dE d\vartheta d\varphi = \alpha' n_e^2, \qquad (1)$$

where ρ is the density of the atmosphere, $f(E)$ is the ion formation coefficient indicating how many pairs of ions form one electron with the energy E at passing 1 g. of matter. It is accounted in the formula, that at $\vartheta \neq 0$, the electron creates at passing the horizontal layer ϑ times more ions/s, than the vertically incident electron. The energy flux of electrons I will be $I = Q\varepsilon$, where ε is the energy lost by the electron at formation of a single pair of ions. For electron energy $E > 4 \cdot 10^3$ eV for atmospheris constituents $\simeq 30$ eV and for lower values E, the magnitude ε will somewhat increase [41]. The magnitudes $\alpha' n_e^2$ and $\alpha' n_e^2/\rho$ are respectively presented in Fig.1 (I and II) and in the Table hereafter. The following initial data have at the same time been utilized.

h, км	n_e, $см^{-3}$	α', $сек^{-1}$ $см^3$	$\alpha' n_e^2$, $сек^{-1}$ $см^{-3}$	ρ, г $см^{-3}$	$\alpha' n_e^2/\rho$, $г^{-1}$ $сек^{-1}$	ρ_h, г $см^{-2}$	E', эв	$f(E')$, ион. $г^{-1}$ $см^2$	$\frac{\partial E'}{\partial \rho_h}$, эв. $г^{-1}$ $см^2$	электронов × $см^{-2}$ $сек^{-1}$ × $эв^{-1}$
290	$5 \cdot 10^5$	$7 \cdot 10^{-8}$	$1,7 \cdot 10^4$	$4,0 \cdot 10^{-14}$	$5 \cdot 10^{17}$	$1,4 \cdot 10^{-7}$	90	$5,5 \cdot 10^6$	$1,1 \cdot 10^9$	$4,1 \cdot 10^8$
250	$4 \cdot 10^5$	$2 \cdot 10^{-7}$	$1,5 \cdot 10^4$	$9 \cdot 10^{-14}$	$1,7 \cdot 10^{17}$	$3,2 \cdot 10^{-7}$	200	$5 \cdot 10^6$	$3,5 \cdot 10^8$	$8,5 \cdot 10^7$
200	$7 \cdot 10^4$	$6 \cdot 10^{-7}$	$3 \cdot 10^3$	$2,5 \cdot 10^{-13}$	$1,2 \cdot 10^{16}$	$1,1 \cdot 10^{-6}$	440	$3,4 \cdot 10^6$	$2,4 \cdot 10^8$	$1,9 \cdot 10^6$
180	$2 \cdot 10^4$	$7 \cdot 10^{-7}$	$3,8 \cdot 10^2$	$4,5 \cdot 10^{-12}$	$7 \cdot 10^{14}$	$1,5 \cdot 10^{-6}$	500	$3,2 \cdot 10^6$	$2,1 \cdot 10^8$	$9,5 \cdot 10^5$
160	$1 \cdot 10^4$	$8,5 \cdot 10^{-7}$	$1,3 \cdot 10^2$	$1 \cdot 10^{-12}$	$1,3 \cdot 10^{14}$	$3,0 \cdot 10^{-6}$	800	$2,5 \cdot 10^6$	$1.7 \cdot 10^8$	$2,0 \cdot 10^5$
140	$8 \cdot 10^3$	$9,3 \cdot 10^{-7}$	60	$3 \cdot 10^{-12}$	$2 \cdot 10^{13}$	$6,5 \cdot 10^{-6}$	$1,1 \cdot 10^3$	$2,2 \cdot 10^6$	$1.3 \cdot 10^8$	$1,9 \cdot 10^4$
120	$7 \cdot 10^3$	$1 \cdot 10^{-6}$	50	$2 \cdot 10^{-11}$	$2,5 \cdot 10^{12}$	$2,5 \cdot 10^{-5}$	$3,2 \cdot 10^3$	$1.4 \cdot 10^6$	$8.3 \cdot 10^7$	$1,9 \cdot 10^2$
110	$5 \cdot 10^3$	$1 \cdot 10^{-6}$	25	$5 \cdot 10^{-11}$	$5 \cdot 10^{11}$	$7,0 \cdot 10^{-5}$	$5,6 \cdot 10^3$	$1.0 \cdot 10^6$	$5,3 \cdot 10^7$	$5,7 \cdot 10^1$
100	$4 \cdot 10^3$	$1 \cdot 10^{-6}$	16	$2,5 \cdot 10^{-10}$	$6,5 \cdot 10^{10}$	$2,0 \cdot 10^{-4}$	$8 \cdot 10^3$	$9 \cdot 10^5$	$3,2 \cdot 10^7$	5,7
90	$1 \cdot 10^3$	$1 \cdot 10^{-6}$	1	$5 \cdot 10^{-9}$	$2 \cdot 10^8$	$2,0 \cdot 10^{-3}$	$1,5 \cdot 10^4$	$7 \cdot 10^5$	$4 \cdot 10^6$	$4 \cdot 10^{-2}$

Up to the present time several curves were obtained with the help of rockets, giving the nightime distribution of electron concentration n_e as a function of altitude. K. I. Gringauz [42, 43] measured the electron concentration in the 100 – 200 km altitude range during late evening (19 54) hours. Jackson and Seddon [11, 44, 45 and 46] obtained data in the middle of night (00 17 hours) in the 80 – 200 km region. Nisbet [47] made the analysis of several curves nighttime electron density distribution above 200 km. Column 2 of the above Table provides the lowest values of n_e according to these data. The density of the atmosphere ρ, measured with the aid of rockets and satellites, was taken according to the work by Mikhnevich and al. [48]. The magnitude

$$p_h = \int_h^\infty p\,dh.$$

In calculating $\alpha' n_e^2$ the α' values were taken according to Danilov work [8], while admitting that for the reaction of dissociative recombination $M^+ + e \rightarrow A_1 + A_2$, the rate factor is $\alpha^* = 10^{-6}$ The experimental determinations of that magnitude give a spread within the bounds of one order. Taking another possible extreme boundary value $\alpha^* = 10^{-7}$ (see [10]), we find that all magnitudes $\alpha' n_e^2$ must be diminished by one order, correspondingly. The total number of recombinations in the night ionosphere column of 1 cm^2 cross section will be :

$$\int_0^\infty \alpha' n_e^2 dh = 2\cdot 10^{10} \div 2\cdot 10^{11}\ см^{-2} сек^{-1}, \qquad (2)$$

and under equilibrium conditions it is equal to the number of ionization acts. Inasmuch as each act of ionization in the atmosphere consumes an energy ε, the total energy flux of electrons absorbed in a ionosphere column of 1 cm^2 cross section, is according to (2) :

$$\pi \int_0^\infty n(E) E\,dE = (2\cdot 10^{10} \div 2\cdot 10^{11})\ \varepsilon\ эрг\cdot см^{-2}\ сек^{-1}. \qquad (3)$$

It is important to stress, that this estimate of electron energy flux coincides by its order of magnitude with that of thermal energy flux, lost by the ionosphere on account of heat conductivity and microwave emission of atomic oxygen, which is $\sim 0.5 - 1$ erg/cm^2·s. [49, 50]. The source of that thermal energy has not so far been found. Meanwhile, the currently assumed electron flux obviously must expend together with the ionization a substantial share of its energy for the heating of the atmosphere gas too.

Let us estimate the effective value of electron energy and of their number. The spectrum of fast electrons in aurorae was experimentally determined with the help of rockets by Meredith and al. [51] and by McIlwain [52]. In the lower part of the inner radiation belt it was determined by Holly and Johnson [53], and in the outer belt by Walt and al [54]. The approximation of the electron spectrum within the 8 to 4000 keV energy range by the exponential law $n(E)\,dE \sim E^{-\gamma}dE$ gives the value 4 – 5 for the magnitude γ . A similar steep spectrum was found by Anderson [55] for sporadic electron fluxes at about 100 km altitude according to their X-radiation brehmstrahlung registered by means of balloons. Because of spectrum steepness, the number of electrons and their energy flux are basically determined by the softest electrons. Thus, we have in the upper part of the ionosphere *)

$$\int n(E)E\,dE \simeq \beta E_{эф} E_{эф}\, n(E_{эф}), \tag{4}$$

where the effective value of energu is determined by the lower boundary of the spectrum, while $\beta E_{эф}$ is about equal to spectrum's half-width, β being the factor depending on the kind of electron spectrum : for the exponential law $\beta = 1/(\gamma - 2)$.

For a preliminary estimate we shall admit that the electron flux has an axial symmetry relative to the vertical, and that an isotropic electron flux is incident from the upper half-sphere on the horizontal plane in the ionosphere (see the following chapter).

*) We shall retain in the following formulas "эф" for "eff"

In this case (1) will be rewritten in the form :

$$2\pi\rho\int_0^\infty n(E;\, h)\cdot f(E)dE = \alpha' n_e^2. \tag{5}$$

As for (4), we shall obtain for (5), that at any altitude h:

$$2\pi\delta E_{э\phi}\cdot n\,(E_{э\phi})\cdot f(E_{э\phi}) = \frac{\alpha' n_e^2}{\rho}, \tag{6}$$

where $E_{э\phi}$ and δ are sufficiently near the magnitudes $E_{э\phi}$ and in the expression (4). The magnitude $\alpha' n_e^2/\rho$ factually expresses in (6) the ionizing capability of electrons with effective energy $E_{э\phi}$. It may be seen from the Table that this magnitude sharply increases in the direction toward the ionosphere layer maximum, and remains nearly constant above the maximum, as is shown by computations (dots of Fig. 1, corresponding to uncertain values, point even to that magnitude's decrease), thus attesting the constancy of electron flux in the upper part of the ionosphere. For that part we have $\alpha' n_e^2/\rho \simeq 5\cdot 10^{17}$, whence from (6), together with (3) and (4) we shall obtain :

$$\frac{f(E_{э\phi})}{E_{э\phi}}\cdot\varepsilon = 1.25\cdot 10^6\ см^2\, г^{-1}. \tag{7}$$

This allows the estimate of the effective energy of electrons.

Let us note that the expression (7) does not practically depend on the admitted value for α'. This is obvious if we take another value α^*, inasmuch as $\alpha' \sim \alpha^*$. But even if we take quite different values for the effective recombination coefficient, such as the Mitra data, for instance, [56], the numerical multiplier in (7) will be equal to $4\cdot 10^5$, i.e. it will vary little in substance.

Admitting for a preliminary estimate, that the atmosphere mainly consists of molecular nitrogen to 300 km heights [9], we shall obtain from (7) that $E_{э\phi} \simeq 200$ eV. At the same time, taking (3) into account, the total number of electrons in the flux will be

$$\sim 5\cdot 10^9 \text{ to } 5\cdot 10^{10}\ \text{cm}^{-2}\,\text{sec}^{-1}.$$

Thus, in order to explain the night ionization of the ionosphere by corpuscules, it is necessary to admit the existence in the upper atmosphere of a sufficiently powerful flux of comparatively soft electrons. Let us attempt to effect a more precise computation of the electron spectrum.

COMPUTATION OF THE ELECTRON ENERGY SPECTRUM

In order to compute the electron spectrum, we shall consider that an electron stream, with a certain distribution spectrum by energies, is incident upon the ionosphere from above.

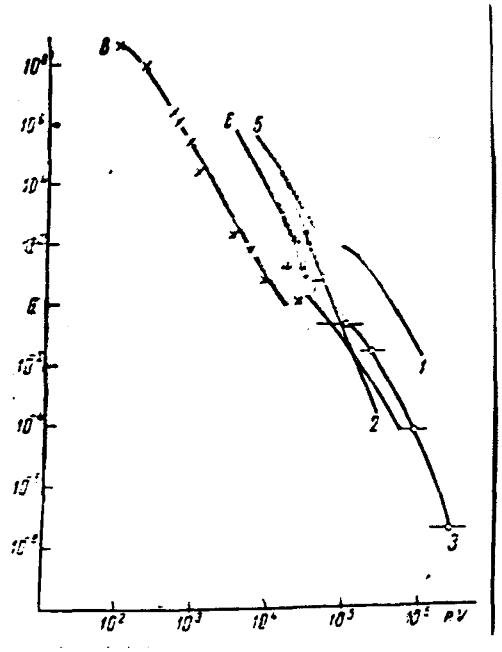

Fig. 2. Electron energy spectra according to data: 1 — Wault & al [54]; 2 — Anderson [55], mean spectrum being computed by X-brehmstrahlung; 3— Holly, Johnson [53] (in relative units); 4 — Krasovskiy & al. [24]; 5 — McIlwain [58]; 6 - Meredith & al. [51]; 7 — Kupperian & Friedman [60]; 8 — computed in the current work.

As it penetrates the ionosphere, this stream will ionize the atmosphere constituents. Fitst the softer electrons, then the harder ones will leave the stream, inasmuch as the effective ionization cross section decreases as the electron energy increases. In fact, electrons with energy E surrender the basic part of their energy in the narrow ionosphere layer prior to reaching the end of their path at the altitude, where the mass of the atmosphere is about equal to $E/f(E)\varepsilon$. At the same time, it is obvious that the electrons will undergo multiple collisions, and the velocity distribution of such electrons in the stream will be nearly isotropic. This must be taken into account when computing the ionization, inasmuch as the electron, passing obliquely through a certain ionsophere layer, will produce more ions, than the vertically-incident electron.

As is shown by the computations, the length of the path, and thus the ionization created by a stream at its passing a layer of specific height, is increased twofold as an average at isotropic velocity distribution of electrons in the stream. A certain effect upon the length of electron path will be also exterted by the magnetic field. However, inasmuch as the basic energy at every altitude is borne by the softest electrons, and the basic share of their energy is lost by electrons when their velocity distribution is isotropic on account of the steepness of the electron spectrum, the magnetic field's influence must not be taken into account.

Let us admit that only electrons with energy $\geqslant E'$, characterized by the path

$$\rho_l = \rho_h/\cos\vartheta, \quad \text{where} \quad \rho_h \equiv \int_h^\infty \rho\, dh.$$

may penetrate to the level h in the ionosphere.

If the electron velocity distribution in the stream is isotropic, $\bar{\rho}_l = 2\rho_h$. In that case, the equation (5) will take the form:

$$2\pi \int_{E'(\rho_l)}^{\infty} n(E)\cdot f(E)\,dE = \frac{\alpha' n_e^2}{\rho}. \tag{8}$$

At the same time, it is considered that the kind of spectrum n (E) does not vary at electron flux' passing through the ionosphere, which is only approximately correct.

Let us resolve the equation (8) by way of differenciating both parts by the parameter ρ_h, which gives the following expression for the energy spectrum of electrons in the stream:

$$\pi n(E') = \frac{\dfrac{\partial}{\partial \rho_h}\dfrac{\alpha' n_e^2}{\rho}}{2f(E')\dfrac{\partial E'}{\partial \rho_l}\dfrac{\partial \rho_l}{\partial \rho_h}}. \tag{9}$$

The results of computations by that formula are brought out in the Table. The values of the magnitudes $f(E')$ and $\frac{\partial E'}{\partial \rho_l}$ were taken according to the informatory data in reference [57], pp. 343, 347.

For small values of energy $E' < 3 \cdot 10^3$ eV data on ε from reference [41] were used. The obtained electron spectrum (see Fig. 2) results to be a power-law spectrum with $\gamma = 4.5$.

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DISCUSSION OF THE RESULTS

Let us compare the results of the above computations with the experimental data about the energy spectrum of electrons in the upper atmosphere obtained with the aid of rockets and satellites.

The results of measurements of the spectrum are plotted in Fig. 2. The first measurements of the spectrum of particles were conducted by Meredith and collaborators [51] with the help of rockets launched in the luminescent formations of aurorae. Electrons were observed only in those formations. Their spectrum was roughly estimated. It was shown that the electron flux with energy $\geqslant$ 8 keV is 10 times greater than the electron flux with energy $\geqslant$ 35 keV, while the total flux of electrons with energy $\geqslant$ 3 keV constituted about 5 erg/cm^2 sec$\cdot$ sterad.

More detailed measurements of electron spectrum in the energy region from 3 to 30 keV (also in aurorae) were effected by McIlwain [52, 58] with the help of a magnetic analyzer. Plotted is in Fig. 2 the electron energy spectrum obtained in the region of quiet (passive) aurora luminescence. In another rocket launching, this time in the bright and active aurora arc, the electron stream showed quick variations in time. The electron distribution by energies resulted close to the monoenergetic, with an energy of $\sim$ 6 keV, but insamuch as this energy corresponded to the minimum value detected, the energy spectrum could not be determined with a sufficient precision. The total electron energy flux was 50 times greater in this experiment than in the preceding.

An intense electron flux (~ 30 times more powerful than the proton flux) was registered by the Atlas rocket at ~ 1000 km near the geomagnetic equator (inner radiation belt) by Holly and Johnson [53]. They had conducted the analysis of the electron spectrum in region of 30 to 4000 keV energies by means of six various thin-walled counters. This spectrum is plotted in Fig. 2 in relative units. A particularly powerful electron flux was observed with the aid of a satellite in high latitudes and at 600 – 1000 km altitude within the outer radiation belt by Wault and others [54], who constructed the electron spectrum for the 85 to 1000 keV energy interval. It is interesting to note that the spectrum of electrons, registered by a luminescent counter aboard the third Soviet artificial satellite at an altitude of ~ 1000 km [23, 24, 59], is also similar to spectra obtained by means of other detectors.

All these spectra have been however obtained at great height above the ionosphere, while only indirect measurements of electron flux spectrum were conducted in the ionosphere. Anderson [55] measured the X-ray radiation spectrum in three wavelengths' regions, using scintillation counters aboard balloons in the polar region. By that spectrum he reestablished the spectrum of primary electrons, which generated the registered X-ray brehmstrahlung at passing through the ionosphere. One of the spectra is brought out in Fig. 2. All electron spectra constructed by Anderson, may be represented by the exponential law with $\gamma = 4$ to 5. Anderson measured the X-radiation spectrum during penetrating radiation flares, i.e. during the period of increase in intensity of electron flux. Kupperian and Friedman [60], also using rocket-born scintillation counters, measured the X-radiation spectrum with a great resolving power. They conducted their experiment at middle latitudes, and that is why it is particularly valuable for the examined question about the ionosphere. Similarly to what was done by Anderson, the electron spectrum brought out in Fig. 2 was computed according to data of reference [60]. It may also be represented by the exponential law with $\gamma = 3.8$.

There is little data on electron spectrum as yet, and these experimental data are related to the hard part of the enrgy spectrum. Besides, measurements of corpuscular streams' spectra were carried out in the region of radiation belts, of aurorae etc., in cases when the corpuscular stream intensity increases hundreds and thousands times. Despite this, the character of the spectrum is analogus in all cases, i.e. it has the exponential form with $\gamma = 4$ to 5. The spectrum computed by us also is exponential with $\gamma = 4.5$, and is found in the overlapping region of energies in good agreement with the existing experimental data. The computed spectrum continues also in the region of energies < 3 keV (through 100 eV), where no variations were effected as yet. The intensity of such a spectrum is lower than that observed in all the recalled experiments. This is explained by the fact that it is computed for conditions of unperturbed ionosphere in middle latitudes, when the assumed electron flux must be minimum.

The absence of experimental data on soft electrons is explained by the fact, that the detectors used heretofore (photon counters, ionizatiin chambers, scintillation counters etc.) for the corpuscular and cosmic ray radiations were only sensitive to electrons with $E > 10 - 20$ keV, i.e. they could only measure (and they measured indeed) only the "tail" of the electron energy spectrum. Only in the experiment by Meredith and others [51], was there installed a detector capable of registering a flux $\gg 10^9$ $cm^{-2} sec^{-1} ster.^{-1}$ of soft electrons with a 30 to 1000 eV energy. Out of three rockets, one reached 178 km but no soft electrons were registered. According to data of the Table, electrons with energy $\gg 500$ eV may basically reach 178 km high, while their flux constitutes $\sim 2 \cdot 10^7$ $cm^{-2} sec^{-1} \cdot ster.^{-1}$, i. e. almost by two orders less, that the detector of reference [51] could have felt. This example shows that the soft electron flux could have been measured at sufficiently great heights with the help of that detector or, for example by means of Gringauz' traps [61], still more sensitive.

The main question arising about soft electron fluxes in the ionosphere is — what the mechanism of formation of such electrons is and what is the source of energy for such powerful fluxes ? Only general considerations may be expressed at the present time on the subject. It is obvious that the flux of electrons in the ionosphere cannot be formed by solar corpuscular streams, incapable of penetrating through the Earth's magnetic field. The Earth's radiation belts cannot constitute sources for these fluxes either, for they are approaching the Earth's ionosphere only in the region of high latitudes. Inasmuch as the electron flux above the ionosphere and up to 1000 km remains about constant, as indicated by computations of the magnitude $\alpha' n_e^2/\rho$, while a continuous intensive loss of electrons takes place in the flux, the source of electrons is probably located in the ionosphere itself. One may be inclined to think that electron acceleration takes place as a result of geomagnetic variations on account of the energy of the Earth's magnetic field. Such considerat tions on the origin of fast electrons were brought forth by V. I. Krasovskiy [20], although no concrete mechanism has been proposed as yet. A more detailed analysis of ionospheric data related to the F-layer maxiumum region and above, taking into account the lifetime of flux' electrons, might provide precise data on the angular distribution of electron velocities in the magnetic field, and on their acceleration mechanism. It is interesting to note the V. N. Kessenikh hypothesis [62, 63] on the origin of fast electrons in the ionosphere itself, as a result of β - decay of albedo neutrons. According to his estimates, accounting for the magnitude of the recombination coefficient he admitted for the F_2-layer, and which is $\alpha = 2 \cdot 10^{-10}$, such mechanism may also provide a quantitative explanation of the existence of F_2 - layer's night ionization.

It is quite obvious that the Earth's magnetic field must exert upon the distribution of electron fluxes, and on their sources, a substantial influence. A shortage of fast electrons must be observed at the equator and at the magnetic pole in particular, This apparently is revealed by the observed singularity of ionosphere behavior in those regions of the Earth. Electrons fluxes must also lay an notable imprint on the pattern of the daylight ionosphere.

According to [8], the agent, responsible for the formation of the F-layer in daylight, has a significantly higher absorption cross section by atmospheric constituents, that the Sun's ultraviolet radiation. It is possible that the flux of soft electrons may be that agent.

Electron streams often strengthen over specific regions, inducing a nonhomogeneity in the ionosphere, This must lead to local variations of the Earth's magnetic field.

All these questions must be examined separately.

***** THE END *****

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